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Technical Memorandum 6 - 59

EVALUATION OF SIGHTING DEVICES FOR A SMALL HAND-HELD ROCKET LAUNCHER

human ENGINEERING LABORATORY

ABERDEEN PROVING GROUND, MARYLAND

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Report Number
Technical Memorandum 6-59

EVALUATION OF SIGHTING DEVICES FOR A SMALL HAND-HELD ROCKET LAUNCHER

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ABSTRACT

This study investigated the degree of differance in accuracy due to aiming error between three types of experimental sighting devices: An iron sight with a twenty inch sight radius utilizing a plexiglass plate upon which a reticle was etched for the front post (Sight "A"), a unity-power optic using singlet lenses (Sight "B"), and a unity-power optic using doublet lenses (Sight "C").

Twenty-eight Infantry men from Fort Dix, New Jersey were used as subjects.

Greater accuracy will be attained with Sight "C" than Sight "B", and Sight "B" will yield better performance than Sight "A".

Determinants of qualitiative disparity between the sights, and possible effects of low illumination sighting are discussed.

CONTENTS

EVALUATION OF SIGHTING DEVICES FOR A SMALL HAND-HELD ROCKET LAUNCHER

INTRODUCTION

The recent progress made in the development of the small rocket, and other related weapon systems has brought forth an old controversy concerning the utilization of the optimum sighting device. Weapon systems are being developed to attain lethal accuracy at various ranges. These weapons decrease in size and complexity as the effective range decreases. However, most shoulder-fired weapons, with the exception of the rifle, have been incorporating an optical sighting system. It was felt that the accuracy attained with this type of sight was far superior to that attained by an open or iron sight, due to the error incurred when aiming the weapon. Most of this error comes as a direct result of the limitations of the eye. The eye can only focus on one object at a time. This does not mean that other objects cannot be seen simultaneously, but that only one object can be seen clearly (1,3,5). When aiming with an open sight the eye is positioned by the rear peep, and picks up the "post" located on the front of the weapon. The front post is then lined up with the target. Either the target or the front post is in focus. When learning to fire one is taught to focus on the front post. When aiming with an optical sight the eye focuses on the target, and due to the design of the scope, the reticle comes clearly into view, presenting target and reticle clearly. Still another difference between the two types of sights is the eye positioning. When properly sighting through an optic the eye can be in only one place. When looking through the rear peep of an iron sight the eye can be placed in a given number of positions depending upon the size of the peephole, resulting in a proportionate error. These two are the prime reasons for the optic sight preference.

During the development of a new small-held rocket launcher, this problem once again became apparent. This rocket launcher is a lightweight (four lbs.), one-shot, throwaway item. The intended sighting device for this system was a unity-power optical scope. The rationale behind the selection of this type of sight was accomplished by a process of elimination. A prism-type sight would be too big, heavy, and expensive for use on this weapon. It was felt that an open sight, due to its short sight radius (twenty inches), would not give a clear enough sight picture to effectively maintain the desired accuracy. This left only an optic scope, and since the ranges involved were not excessive, unity power was all that was deemed necessary.

During a meeting with the various cognizant agencies involved in the development of the system, the question of the optimum sight was discussed. Some of the conferees felt that an iron sight could be employed satisfactorily on the weapon. A pilot study was designed and run to obtain trends in accuracy due to aiming error with both types of sights. The pilot study indicated that an iron sight might meet the accuracy requirements of the weapon. Subsequently the investigation reported here was conducted.

Three sighting devices were used for this study.

1. An iron sight with a twenty-inch sight radius, and having a two and one half millimeter peephole, and a plexiglass plate upon which a reticle was etched. (Sight "A") (Fig 1).

2. A unity-power scope using singlet lenses and having a 5mm exit pupil and a 5° field of view. (Sight "B")

3. A unity-power scope, containing doublet lenses, and a 5mm exit pupil, and a 10° field of view. (Sight "C").

The difference between scopes having singlet or doublet lenses is one of resolution. A clearer picture is obtained with a doublet lens. In general it is accepted as fact that a unity-power scope will permit greater accuracy than an iron sight, and that a unity-power scope with doublet lenses will permit greater accuracy than one with singlet lenses.

The purpose of this investigation was to ascertain the degree of difference in accuracy between the sights, due to aiming error.

METHOD

Range

All test firing took place in a one-hundred (100) yard indoor rifle range. To reduce the possibility of bullets passing through the same hole, this relatively long range was used. This allowed the discernability, and subsequently the measurability of the shot-group patterns. The fact that the range was indoors permitted control of the illumination, and eliminated other environmental conditions such as wind, glare, etc.

Rifles and Ammunition

Three (3) .22-caliber match rifles were used for this study. Round-to-round consistency was insured by using .22-caliber, long-rifle, high-precision, quality-controlled, match ammunition. The mean dispersion of the test rifles using this ammunition, as determined by a machine rest, was found to be .46 foot in azimuth, .47 foot in elevation at 100 yards. (See Table 1).

TABLE 1

ERRORS OF DISPERSION FOR EACH RIFLE AS FOUND BY MACHINE FIRING, AND THE MEAN ERROR

Gun	1	2	3	MEAN
σ AZ	.37	.57	.45	.46
σ EL	.58	.36	.48	.47

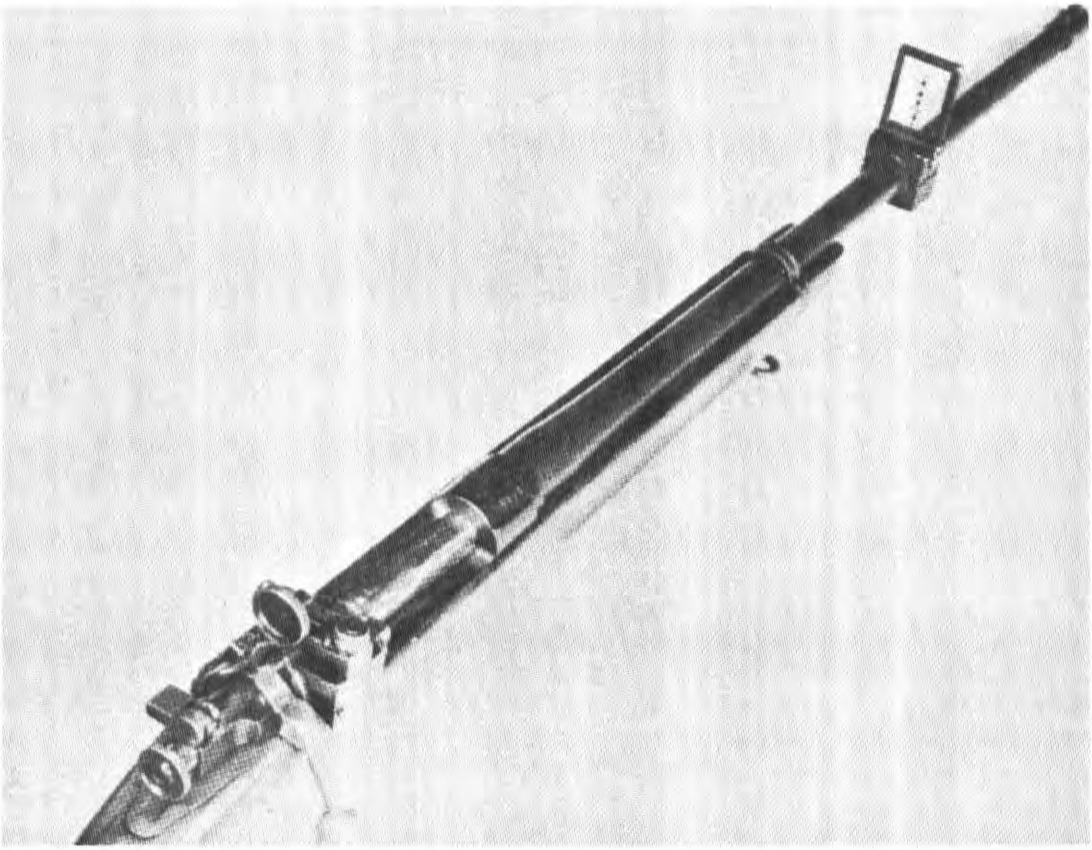


Fig. 1. Iron sight mounted on test rifle.

Targets and Illumination

The targets were specially designed and printed for this study. They consisted of a series of concentric rings, the center being a six-inch black bull's-eye, followed by a three-inch wide white ring, then a three-inch wide black-and-white slashed ring (See Fig 2). This last ring was so drawn as to afford visual prominence to the bull (Fig 3). The target was printed on 38 x 24 inch white paper. In turn the targets were mounted on a black backboard. Three targets were mounted simultaneously. (See Fig 2).

The targets were illuminated by three lamps producing 30-foot candles of incident light.

SUBJECTS

Twenty-eight enlisted men, recently graduated from advanced Infantry Training at Ft. Dix, New Jersey, were used as subjects (Ss). Ages ranged from 17 to 23 years. All had experience in rifle firing. The S's individual rifle proficiencies at the time of their first recorded firing are represented in Appendix "A". Each subject underwent an Orthorater Visual Acuity Test. (Appendix B).

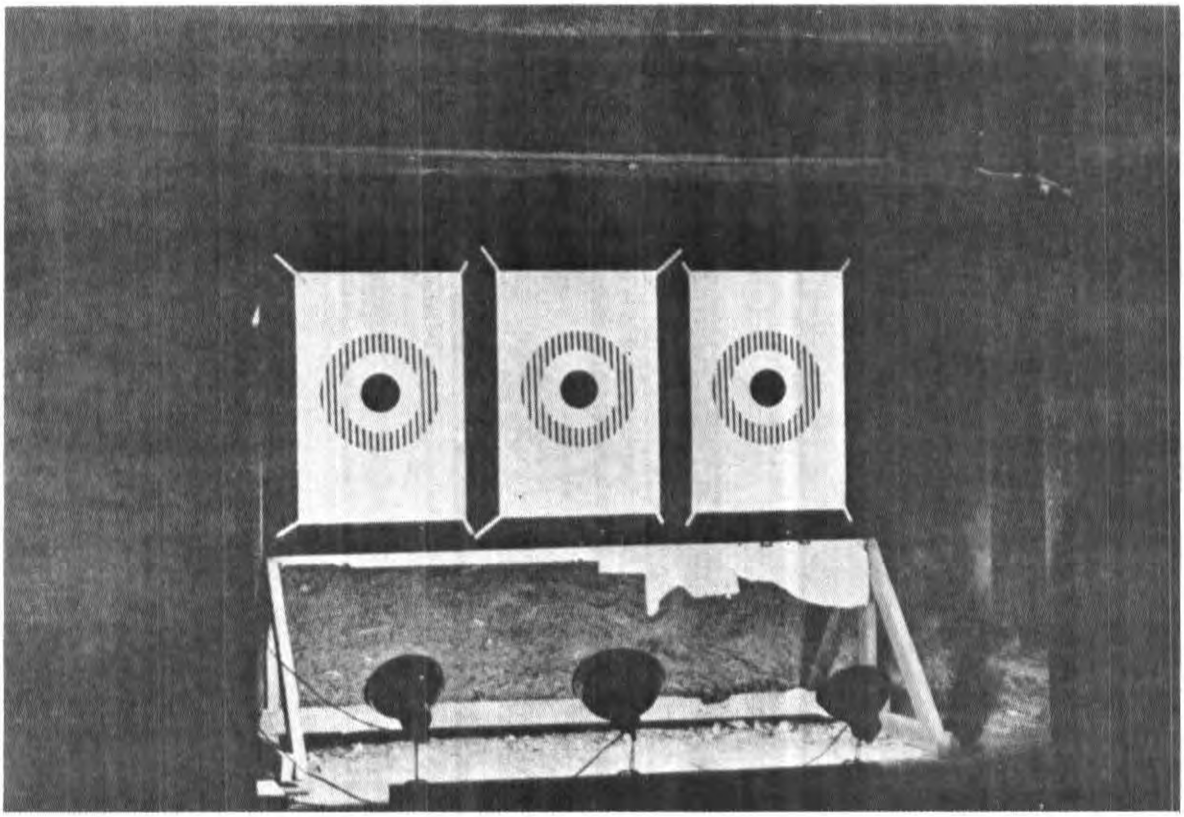


Fig. 2. Design of three-ring targets, as mounted for use in study.

PROCEDURE

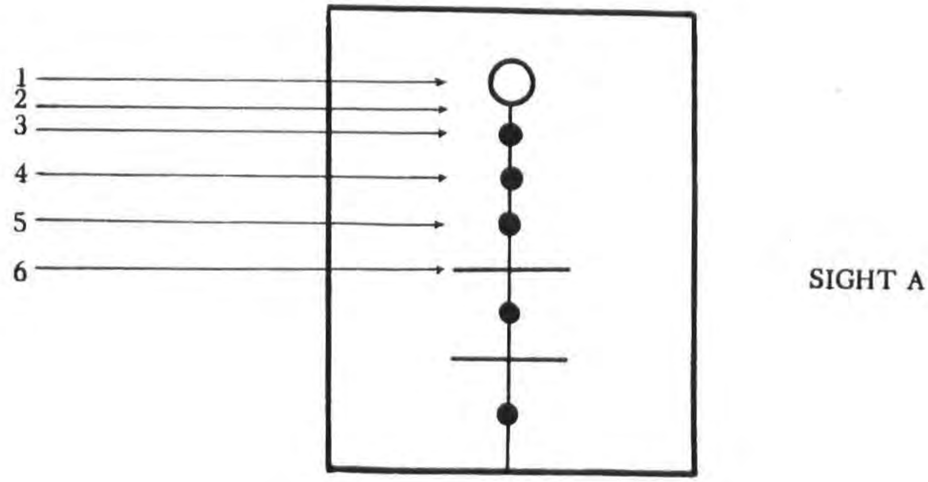
A thorough orientation in the use of the three sights was given to the Ss. The reticles in each sight were broken down to six corresponding aiming points, and were numbered 1 through 6. (See Fig 4).

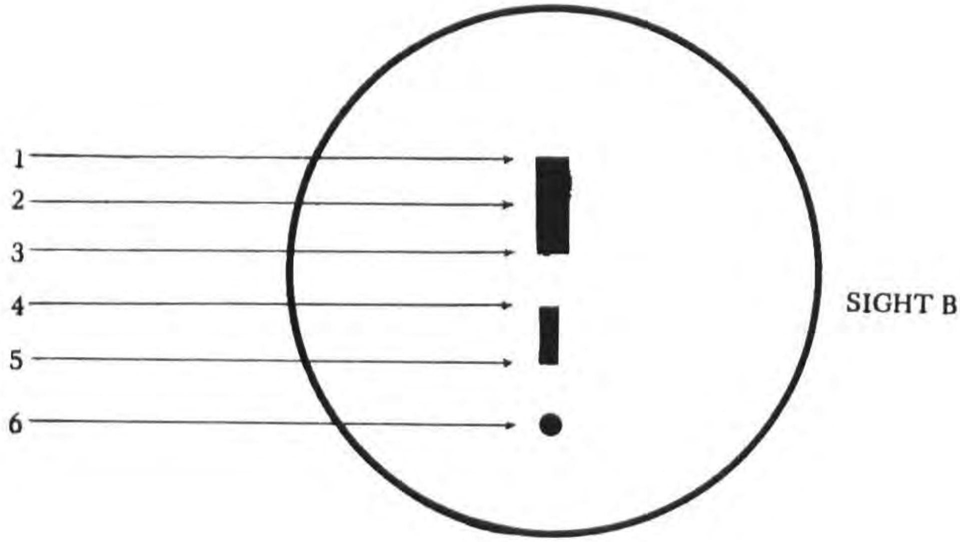
In order to familiarize the Ss with the weapons to be used, each man was allowed to fire two rounds at no particular target. This firing was done without the aid of a sight.

The 28 Ss were randomly assigned into three groups. Group A contained 9 Ss, Group B, 9, and Group C had 10 men. Each S had a numerical designation within his group (i.e., A1, A2, etc.).

Each S experienced three experimental sessions with a different sighting device each day. There were six experimental days. Upon completion of testing each S had used each of the three sights six times, or once with each aiming point.

Each weapon was "zeroed in" on the target for each aiming point by the experimenter (E).





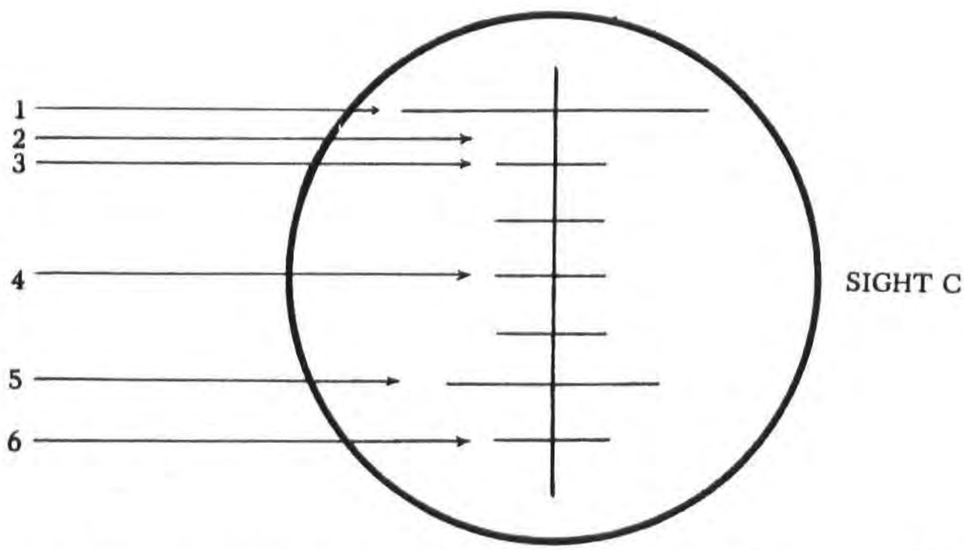


Fig. 4. Rectical Patterns. Diagramatic view of six corresponding aiming points in each retical pattern.

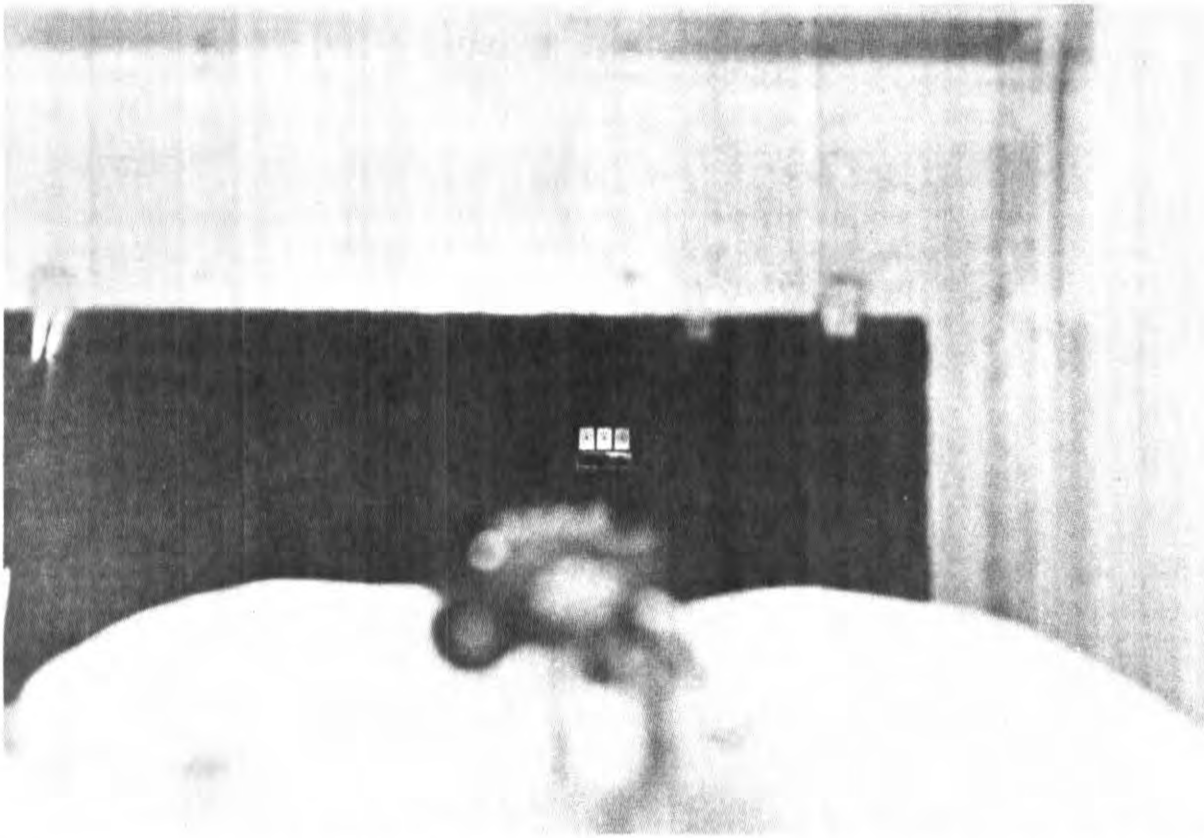


Fig. 3. Visually prominent bull, caused by design of outer ring as viewed from subjects position.

As a S entered the test room, he was met by the E, who informed the S which sight he would be using, and by means of a visual aid, explained which aiming point he should use. The S was then seated in position to fire. This sitting position was selected in order to reduce fatigue and eliminate other human variables. The weapon was supported by a sandbag, and positioned by the S's shoulder. (See Fig 5). The E sat to the right of the S, loading the weapon and operating the bolt. (See Fig 6). This procedure forced the S to take his eye away from the sight after each round was fired. Each S fired a five-round shot group for each of the six aiming points in each of the three sights, thus giving a total of 18 trials.

Ss were permitted to fire at their own rate.

RESULTS

To establish a quantitative measure of dispersion to be expected with each of the three sights due to aiming error, it was necessary to:

a. Measure the S's dispersion about his center of impact, and

b. Measure the dispersion of individual centers of impact about the gross center of impact.

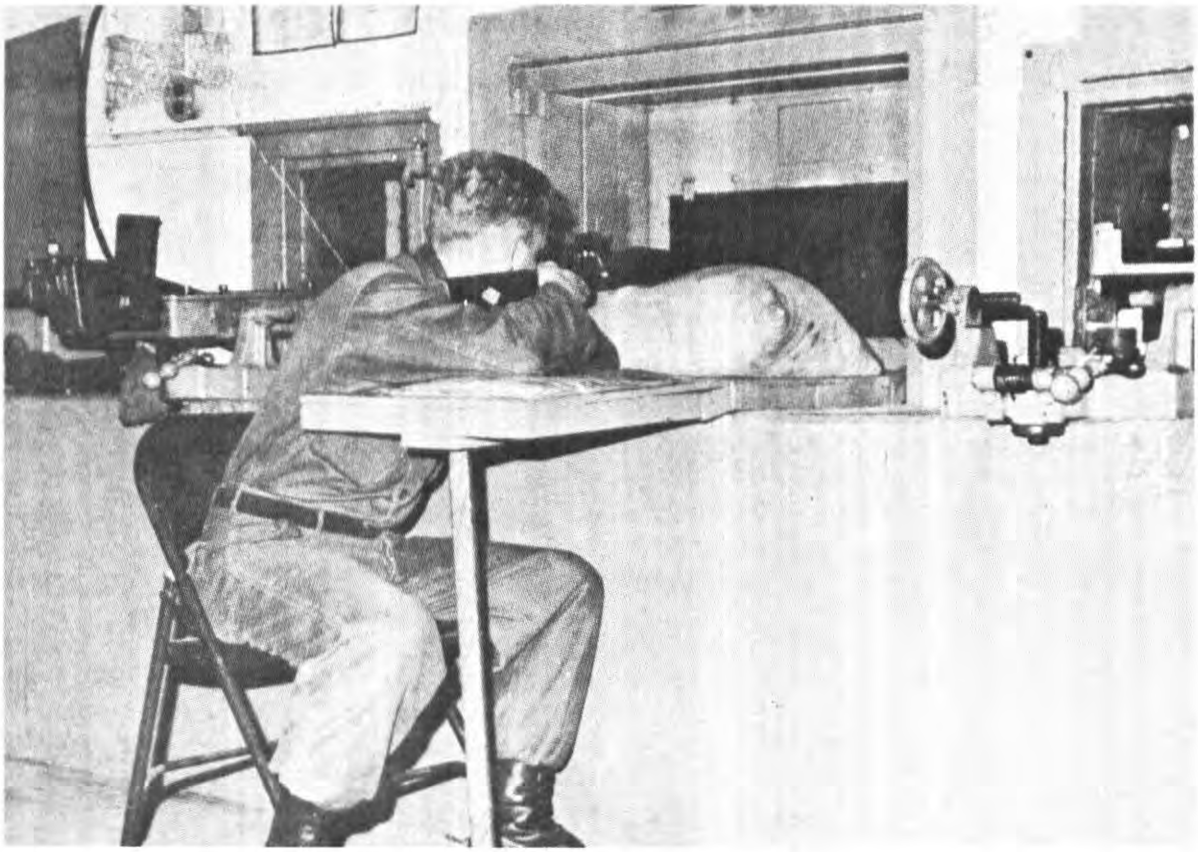


Fig. 5. Subject seated in firing position. Rifle supported by sand-bag, and positioned by subject's shoulder.

The second measure was necessary because the weapon for which this experiment was conducted is "zeroed in" only during assembly.

The "zero" error in the study was removed by establishing the center of impact for the group.

The mean dispersion of the target rifles, (Table 1), was subtracted from the results.

The data were statistically reduced in the following manner:

a. Each of the holes in a shot group was measured and recorded in a rectilinear co-ordinate system with 0-0 in the lower left hand corner. The units of measure in both vertical (y) and horizontal (x) co-ordinates were tenths of a foot.

b. The means ($\overline{xi}$ & $\overline{yi}$) were established for each shot group.

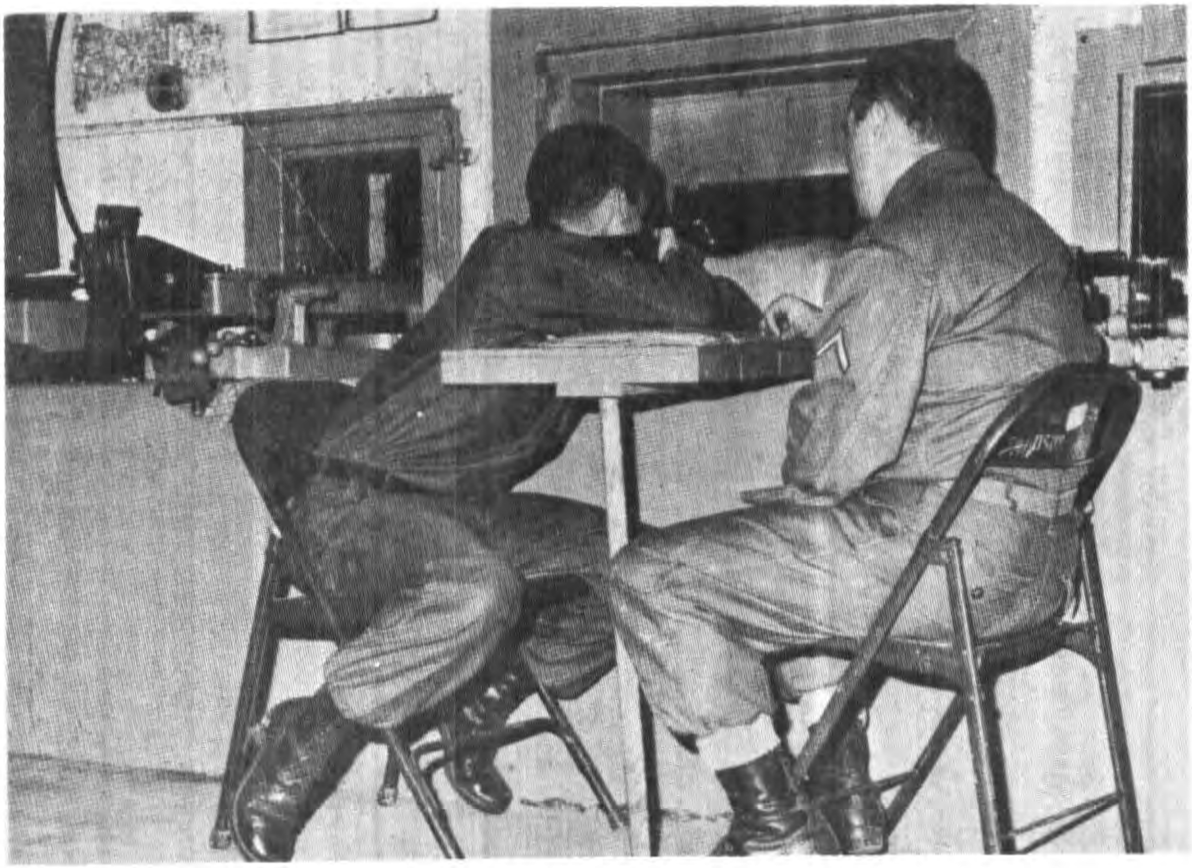


Fig. 6. Position of Experimenter and Subject in testing

c. The dispersions $\sigma_{xi}^2 = \sum_{1}^{5} \frac{(\overline{xi} - xim)^2}{N}$ and

$$\sigma_{yi}^2 = \sum_{1}^{5} \frac{(\overline{yi} - yim)}{N}$$

were calculated.

d. The individuals' dispersion about their means was then taken

$$\sigma_{xg}^2 = \sum_{n=1}^{28} \frac{\sigma_{xin}^2}{28} \quad \text{and} \quad \sigma_{yg}^2 = \sum_{n=1}^{28} \sigma_{yin}^2$$

for each condition, (one aiming point). (Table 2).

e. The mean of the means was determined ($(\overline{X_m} \; \& \; \overline{Y_m})$ for each condition.

f. The dispersion of the means about the gross mean was obtained

$$\sigma_{xm}^2 = \sum_1^{28} \frac{(\overline{X_m} - \overline{X_i})}{28} \quad \& \quad \sigma_{ym}^2 = \sum_1^{28} \left(\frac{\overline{y_m} - \overline{y_i}}{28}\right)^2$$

for each condition. (Table 3).

g. The dispersions were added to give the total dispersion. (Table 4).

$$\sigma_{x9}^2 + \sigma_{xm}^2 = \sigma_x^2 \, , \quad \sigma_{y9}^2 + \sigma_{ym}^2 = \sigma_y^2$$

h. All six conditions were averaged

$$\sigma_{xt}^2 = \sum_1^6 \frac{\sigma_x^2 + \quad \sigma_{x6}^2}{6} \quad , \quad \sigma_{yt} \simeq \frac{\sum \sigma_{y_1}^2 + \quad + \sigma_{y6}^2}{6}$$

and the dispersion of the rifle was subtracted from the total dispersion to give the aiming error.

$$\sigma_{xtA}^2 = \sigma_{xt}^2 - \sigma_{xR}^2 \qquad \sigma_{ytA}^2 = \sigma_{yt}^2 - \sigma_{yR}^2$$

i. The radial aiming error was then calculated

$$\sigma_A = \sqrt{\sigma_{xtA}^2 + \sigma_{ytA}^2}$$

to be 3.0 tenths of a foot for Sight "A" at 100 yards.

2.4 tenths of a foot for Sight "B" at 100 yards.

1.8 tenths of a foot for Sight "C" at 100 yards.

Converted into mils these figures are:

Sight "A" 1.0 mil at 100 yards

Sight "B" .8 mil at 100 yards

Sight "C" .6 mil at 100 yards

TABLE 2

THE INDIVIDUALS' DISPERSION ABOUT THEIR MEANS FOR EACH CONDITION

		Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
SIGHT A	σ^2 AZ	1.87	1.27	1.16	1.59	.84	1.34
	σ^2 EL	2.47	1.61	2.32	3.63	1.66	2.09
SIGHT B	σ^2 AZ	.82	.87	.58	.74	.57	.84
	σ^2 EL	.71	3.26	1.20	.77	.50	2.02
SIGHT C	σ^2 AZ	.76	1.02	.66	.76	.67	.52
	σ^2 EL	1.08	.78	.75	.68	.82	2.19

TABLE 3

DISPERSION OF INDIVIDUAL MEANS ABOUT THE GROSS MEAN PER EXPERIMENTAL DAY

		Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
SIGHT A	σ^2 AZ	2.01*	1.30*	1.78	1.69	1.55	1.39
	σ^2 EL	6.26	5.89	3.70	2.44	3.93	6.18
SIGHT B	σ^2 AZ	3.73*	6.60*	.79	1.28	.51	.99
	σ^2 EL	2.94	8.58	2.80	1.16	.70	2.54
SIGHT C	σ^2 AZ	7.86*	8.65*	.78	.63	.41	.36
	σ^2 EL	1.56	.97	1.05	.96	1.85	2.17

TABLE 4

TOTAL DISPERSION PER EXPERIMENTAL DAY

		Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
SIGHT A	σ AZ	1.97*	1.60*	1.72	1.81	1.55	1.65
	σ EL	2.95	2.75	2.45	2.46	2.36	2.87
SIGHT B	σ AZ	2.13*	2.73*	1.17	1.42	1.04	1.35
	σ EL	1.91	3.44	2.00	1.39	1.10	2.14
SIGHT C	σ AZ	2.94*	3.11*	1.20	1.18	1.04	.94
	σ EL	1.63	1.32	1.34	1.63	1.63	2.09

* - Signifys data that was not used in compiling the final results because it was felt to be in error for sights "B" and "C".

DISCUSSION

The degree of difference found between the three sighting devices cannot simply be stated as being significant or insignificant. The significance can only be measured in light of other existing variables.

To apply these results to a weapon system it is necessary to multiply them by the prescribed range factor, and introduce this value into the Hit Probability Formula. By comparing these gained results the degree of difference becomes apparent. This significance evolves as a direct result of the magnitude of the other conditions such as ranging error, environmental conditions, recoil, round stability etc., which are included in the Hit Probability Formula.

While this experiment was conducted to find an answer to the sighting problems of a particular system, it was felt that it contains generalities which may help to solve sighting problems on other systems. It was felt that more information was needed in this area, and to gain some indications that could directly affect the use of these sighting devices the E's, upon completion of the reported study, introduced a new condition. The illumination was reduced to 0.1 foot-candle of incident light. This illumination represented late dusk as the targets were just barely visable.

The same procedure as is reported above was followed for one experimental day. The same aiming point (No. 3, Fig. 4) was used for each of the three sights under this condition. It must be remembered that this study was not designed for low illumination firing. The sharp black and white contrasts of the target and the black backboard served to aid the Ss greatly in aiming. The results were not intended to be difinitive, but merely to give an indication of what can be expected from these sighting devices under this condition of illumination. The data were reduced in the same manner as described earlier. The radial errors of dispersion found under this condition were:

Sight "A" 3.3 tenths of a foot at 100 yards.
Sight "B" 2.99 tenths of a foot at 100 yards.
Sight "C" 2.31 tenths of a foot at 100 yards.

Converted into mils the errors are:

Sight "A" 1.1 mils at 100 yards.
Sight "B" .99 mils at 100 yards.
Sight "C" .77 mils at 100 yards.

Of course only one aiming point was used for this low level phase, and as indicated above, the conditions were not representative of a true low light level environment. Therefore, the errors found are probably smaller than those which would be found under true dusk conditions.

It was felt that the empirical evidence observed by the Es was more indicative of degraded performance than the mathematical results. The Es observed the Ss taking from two to three times as long to aim and fire under this low illumination, indicating the difficulty of the task.

When firing with the iron sight, the Ss constantly took their eyes away from the sight to look at the target. Upon questioning, the Ss reported that they were unable to attain a sight picture, and did not actually aim at the bull because they could not see it. Instead, they estimated the location of the center of the target and fired at it. Because the target was white against a black background, they could distinguish it fairly easily. Consequently, the greatest time consumption occurred with the use of the Iron Sight. The Ss reported that they had little trouble seeing the bull with sight "C", and could just barely see the bull with sight "B". If it is anticipated that a weapon would have a high degree of use at periods of dawn or dusk, this error and time factor would become important.

The difference in performance found between the sights as a result of the main experiment showsthat increased accuracy may be a function of the degree of refinement of the sighting device. Upon finding that the most complex sight was not overwhelmingly better at this short range, the Es introduced a 2.5 power telescope (Fig 7), containing a simple cross-hair reticle, for limited testing. The purpose was to get some indication as to the increase in performance from a still more highly refined sighting device.

As with the low illumination condition, the number of trials was limited. Each S fired one five-round shot group using the telescope. The illumination was the same as that used in the main experiment, 30 foot-candles of incident light.

The results from this condition showed a radial dispersion error of 1.1 tenths of a foot at 100 yards or .37 mils.

While the results obtained with the telescope have to be qualified, it was felt that an indication of improved performance exists. Assuming the findings from the utilization of the telescope to be true, the improvement was twice that of sight "C", (the best sighting device). However, at the short range used in testing, the actual degree of improvement was small. Thus, it is felt that the differance in accuracy between these sights is dependent on the degree of refinement, and that at a given point in range, the accuracy attained with each sight will degrade in a non-systematic manner. It would appear then to be impractical to employ a complex sighting device for use at short ranges, unless other errors involved in the hit probability demanded it.

CONCLUSIONS

1. The present study ascertained the quantitative and qualitative disparity between the three sighting devices. Greater accuracy will be attained with sight "C" than sight "B", and sight "B" will yield better performance than sight "A".

2. The degree of difference found between the sights becomes significant only in light of other existing variables in the weapon to which the sight would be applied, and the range factor.

3. A low level of illumination greatly increases the amount of time needed to aim and fire. This is true particularly in the case of sight "A".

4. The difference in accuracy between the sights is a function of the degree of refinement, which in turn reflects the effective range limits.

Fig. 7. 2.5 Power telescope mounted on test rifle.

RECOMMENDATIONS

1. Additional research should be conducted to discover those ranges where it becomes advantageous to change from an iron sight to a unity-power optic, and from a unity-power scope to a multiple-power telescope.

2. Research should be conducted to determine the effects of low illumination conditions on sighting.

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APPENDICES

A. Subjects' Rifle Proficiency At The Time Of Their First Recorded Firing.

B. Visual Acuity For Both Far And Near Vision In The Right Eye Of The Subjects As Recorded By The Orthorator Visual Acuity Test.

APPENDIX A

SUBJECTS' RIFLE PROFICIENCY AT THE TIME OF THEIR FIRST RECORDED FIRING

SUBJECTS	PROFICIENCY	SUBJECTS	PROFICIENCY
A-1	Sharpshooter	B-6	Marksman
A-2	Marksman	B-7	Sharpshooter
A-3	Sharpshooter	B-8	Marksman
A-4	Marksman	B-9	Marksman
A-5	Bolo	C-1	Expert
A-6	Marksman	C-2	Marksman
A-7	Marksman	C-3	Marksman
A-8	Marksman	C-4	Sharpshooter
A-9	Sharpshooter	C-5	Bolo
B-1	Sharpshooter	C-6	Bolo
B-2	Bolo	C-7	Marksman
B-3	Sharpshooter	C-8	Marksman
B-4	Marksman	C-9	Sharpshooter
B-5	Sharpshooter	C-10	Marksman

APPENDIX B

VISUAL ACUITY FOR BOTH FAR AND NEAR VISION IN THE RIGHT EYE OF THE SUBJECTS AS RECORDED BY THE ORTHORATOR VISUAL ACUITY TEST

SUBJECTS	NEAR VISION	FAR VISION	SUBJECTS	NEAR VISION	FAR VISION
A-1	9	7	B-6	11	11
A-2	11	11	B-7	10	10
A-3	11	10	B-8	10	11
A-4	11	13	B-9	11	12
A-5	10	13	C-1	10	9
A-6	12	11	C-2	11	12
A-7	11	12	C-3	9	9
A-8	13	12	C-4	13	12
A-9	13	13	C-5	9	9
B-1	11	12	C-6	13	12
B-2	13	12	C-7	11	12
B-3	11	12	C-8	11	12
B-4	11	9	C-9	8	7
B-5	10	8	C-10	13	13

KEY: Score	Snellen	Score	Snellen
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Attn: Ch, Human Factors Div. 1 cy

Canadian Army Staff (Washington)
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Washington 8, D. C. 1 cy

Operations Research Office
7100 Connecticut Ave.
Chevy Chase, Maryland 1 cy

American Institute for Research
410 Amberson Avenue
Pittsburgh 32, Pa.
Attn: Dr. R. B. Miller 1 cy

The Franklin Institute
20th St & Ben Franklin Parkway
Philadelphia 3, Pa.
Attn: Electrical Eng. Library 1 cy

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Armed Services Technical
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